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TECHNICAL MANUSCRIPT 560

ETHYLENE: ITS ROLE AS AN AIR POLLUTANT

Frederick B. Abeles
Arthur V. Chadwick

SEPTEMBER 1969

DEPARTMENT OF THE ARMY
Fort Detrick
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ETHYLENE: ITS ROLE AS AN AIR POLLUTANT

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PLANT SCIENCES LABORATORIES

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ABSTRACT

The role of ethylene as an air pollutant has received little attention compared with other pollutants such as carbon monoxide, nitrogen dioxide, sulfur dioxide, ozone, and peroxyacetyl nitrate. What makes ethylene such an unusual and dangerous pollutant is the fact that it is a plant hormone and many of its detrimental effects are associated with the disruption of the normal hormonal regulation of the plant. Some of the important effects of ethylene on plants and the amounts required to cause a response are well known. However, little is known concerning levels of ethylene in the air, the major sources of ethylene, and the mechanisms by which ethylene is removed or destroyed.

ETHYLENE: ITS ROLE AS AN AIR POLLUTANT*

The simplest plant hormone is a two-carbon gas, ethylene. Its effects on plants are varied and include: defoliation,[1] promotion of ripening,[2] growth inhibition,[3,4] inhibition or promotion of flowering,[5,6] flower fading,[7] stimulation of seed germination,[8] inhibition of phototropism and geotropism,[9] epinasty,[9] induction of adventitious roots and plant tumors,[9] acceleration of senescence,[10] and changing the sex of flowers.[11]

These effects of ethylene have been the subject of a number of excellent reviews.[12,13]

All of the above-mentioned processes are induced by low concentrations of ethylene. For the most part, investigators have found that 0.01 ppm will initiate recognizable effects, 0.1 ppm is half maximal, and 1 ppm is a nearly saturating dose of the gas.[1,14] The duration of exposure to ethylene necessary to elicit the above effects varies. Flower fading[7] and ripening[15] are initiated after a relatively short exposure to ethylene because they are autocatalytic processes. A 1- to 3-hour exposure to 0.1 ppm ethylene sets off accelerated ethylene production by the tissues themselves, which in turn accounts for much of the final effect.

A longer exposure is required for non-autocatalytic processes such as defoliation, senescence, and inhibition or acceleration of flowering. Generally speaking, 1 to 2 days are required to elicit a full effect. In the case of growth inhibition, epinasty, and abnormal growth, a continuous supply of the gas is required. Removal of ethylene results in resumption of normal growth, although the malformations themselves remain.

Animals, on the other hand, are practically insensitive to ethylene at low levels and not until the gas phase consists of about 90% ethylene does it cause unconsciousness and narcosis. Ethylene was once widely used as an anesthetic.

The damaging effects of illuminating gas and smoke were described by the end of the 1800's. Neljubow[16] showed that the active constituent was ethylene, and the early work from the Boyce Thompson Institute outlined much of what is known about ethylene's effect on physiology today. Except for a few studies on ripening and abscission, little attention was paid to the role of ethylene in plant growth and development until the work of Stanley Burg demonstrated that ethylene could be measured rapidly, specifically, and in very small amounts with a gas chromatograph. Since that time, interest in ethylene has grown phenomenally.

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We now know that ethylene is produced by all plants and that rates of production vary from one part of the plant to another. Generally speaking, ripening fruits and senescing flowers produce the greatest quantities of ethylene. According to the best available information, the amino acid methionine is the precursor of ethylene in plants.[17] The mechanism of ethylene action is the subject of intensive investigation, and data showing effects of ethylene on nucleic acid metabolism, protein synthesis, auxin transport, and auxin synthesis have been used to explain ethylene action.

Reports of damaging effects of ethylene on plants have increased since the early observations of detrimental effects of illuminating gas on plants.

Some recent examples of plant damage attributed to ethylene include losses of $70,000[18] and $150,000[19] by flower growers in San Francisco and Chicago. Only recently have workers concerned with air pollution begun to study ethylene levels in the atmosphere, and preliminary reports show damaging levels of ethylene, 0.07 to 0.20 ppm, within urban centers.[18] The automobile is a major contributor of ethylene to the air. We have found that along with other plant-damaging gases, automobile exhaust contains 500 ppm ethylene. This is far higher than other plant-damaging constituents of exhaust such as CO (100 ppm), NO_2 (0.1 ppm), and, after irradiation, O_3 (0.2 ppm). Assuming that the exhaust could be contained, we estimate that an idling car produces enough ethylene in 1 minute to defoliate a full-grown tree. The influence of automobiles can be seen in the following figures. We have found that air in a local shopping center parking lot contained 0.05 ppm ethylene; along a local highway 0.010 ppm; and in an intersection, 0.10 ppm ethylene. These figures are in contrast to 0.001 ppm to 0.005 ppm in rural areas.

Another source of ethylene is industry. Ethylene concentrations downwind of industrial polyethylene plants ranged from 0.04 to 3.0 ppm and effects on plants were noticeable as far as 2 miles from the plant.[20]

Burning plant material produces large amounts of ethylene. We have found that cigarette smoke contains between 500 and 1,000 ppm ethylene. Interestingly enough, filters, charcoal or otherwise, have little effect on the amount of ethylene produced by a smoker.

To summarize, we know that low levels (0.1 ppm) of ethylene cause plant damage in the form of defoliation, abnormal growth, and loss of blossoms. An exhaustive study of detrimental effects of ethylene to 114 agronomic plants was published by Heck and Pires.[21] On the other hand, we know little about the ethylene part of the carbon cycle in nature. Little information is available on the relative contribution of ethylene to the air by man as opposed to plants and, similarly, we have scant knowledge on the removal of ethylene by destruction via ozone, UV light, and other mechanisms. We have no idea how much ethylene we can add to the air and still expect natural removal mechanisms to keep ethylene at safe or at least tolerable levels.

Apparently it has become so difficult to raise natural plants in urban areas that the plastic variety has taken over in some form of unnatural ecological succession. On the assumption that the average citizen spends a dime a year on plastic plant replacements, the American public is paying $20 million to overcome the loss of house plants to air pollutants. It is ironic that the plastic most widely used is polyethylene.

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